BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Apollo 7 Launch Phase Air/ Ground Voice Contact Analysis Case 900

DATE: December 30, 1968

FROM: L. A. Ferrara

ABSTRACT

Voice communications with the Apollo 7 spacecraft are examined from lift-off at Cape Kennedy through the pass over the Canary Island MSFN station. Communications intelligibility and quality were different at the several MSFN stations. Down link voice signal quality varied widely. In some cases, transmissions from MCC to and from the spacecraft were not received. For a significant portion of the time from lift-off through the Canary Island transit, MCC either received garbled voice signals or did not receive the spacecraft transmissions. During a portion of this same period, MCC apparently did not have an up voice capability with the spacecraft.

Analysis of MSFN voice recordings and the NET 1 circuit (GOSS Conference) transcript made at MCC indicated that the voice signal anomalies were apparently due to procedural and equipment problems at the MSFN stations.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

Voice communications between the Apollo 7 spacecraft, MSFN ground stations, and Mission Control Center (MCC) during the mission launch phase were observed by Messrs. J. J. Hibbert at the MSFN station at Cape Kennedy, J. T. Raleigh at Corpus Christi, and the writer at LCC 37. The observations were made to evaluate the performance of the interconnecting KSC Operational Intercommunication System-Audio (OIS-A) and the air/ground voice system for this first manned Apollo mission. Communications intelligibility and quality were observed to be different at several locations, ranging in quality from excellent to badly garbled with several instances of transmissions (both to and from the spacecraft) never reaching their destination. Two-way voice communications of both S-Band and VHF voice radio links as recorded at the ground stations having contact during the launch phase were reviewed and compared with the transcript of the NET 1 circuit (GOSS Conference) as heard at the Mission Control Center.

A summary of the air/ground voice contacts as a function of Ground Elapsed Time (GET) is presented in Figure 1 for the period from lift-off to Loss of Signal (LOS) at the Canary Islands station (lift-off plus 24 minutes). As shown in Figure 1, voice communication from the spacecraft to the Mission Control Center in Houston was missing for about 25% of the time and was garbled to some degree for an additional 25% of the time between lift off and LOS at the Canary Islands; during at least 15% of this same period, MCC apparently did not have an up voice communications capability with the spacecraft. In one case, the loss of up voice to the spacecraft occurred just prior to insertion into Earth orbit when some mission critical messages are transmitted by MCC to the crew; these were not heard by the spacecraft crew.

The results of the review of the voice recordings and possible causes for the observed discrepancies are discussed in Section 3.0 of this memorandum. This analysis, while not considered complete due to the unavailability of

all the data, was reviewed with GSFC personnel on November 27, 1968. GSFC has been making a similar analysis and has indicated that it will take appropriate corrective action to eliminate the procedual and technical difficulties noted.

2.0 Voice System Configuration

This was the first manned orbital test of the Unified S-Band (USB) system. The USB voice system was considered to be backup to the prime VHF-AM system in the Apollo 7 mission. The spacecraft and ground stations were in a Duplex B mode of operation for voice communications during the launch phase, transmitting on one VHF frequency and receiving on another. The VHF Duplex B mode was to be maintained during the launch phase, then the prime voice system was to be configured for Simplex A operation for orbital communications. The CSM and MSFN stations both transmit and receive on the 296.8 mHz carrier in the Simplex A mode. During the launch phase, the Apollo 7 CSM simultaneously transmitted voice to the MSFN from the crew over the USB system on a subcarrier of the 2287.5 mHz USB carrier and over the VHF carrier on 259.7 mHz. The CSM was equipped to receive the up voice communications simultaneously on both VHF (296.8 mHz) and USB (2106.4 mHz), although the USB audio volume was deliberately adjusted before lift-off to its lowest setting to prevent loud static from bothering the crew whenever there was no USB carrier present. There was no squelch circuit on the USB audio system in the Apollo 7 spacecraft.

Although the up voice was transmitted simultaneously from the MSFN stations on VHF (298.6 mHz) and USB (2196.4 mHz), the astronauts were instructed to keep the USB volume controls below threshold unless they could not receive the VHF signal. In fact, during one period (about 3 minutes after lift-off) the spacecraft Commander did increase his USB volume thumb-wheel because he could not hear the ground station respond on VHF when he called. This is one of the periods where the contact analysis chart (Key B, Figure 1) shows there was no up link communications from MCC at all, which may have been due to a failure to promptly connect the GBM/GBI ground station to MCC over the NET 1 circuit after the GMIL station was disconnected. Communications were heard in the spacecraft at 3 min: 13 sec after lift-off; it is believed this was due to the restoration of up voice capability on VHF and was not the result of increasing the USB spacecraft receiver volume setting. The USB volume setting used was not adequate to permit hearing the up voice. The crew members can receive VHF, USB or spacecraft intercomm voice signals in their headsets depending on the settings of the spacecraft audio center switches and they are not always able to distinguish which radio link they are listening to.

The MSFN ground station configuration for launch phase voice communications provided simultaneous transmission of VHF (296.8 mHz) and USB (2272.5 mHz). Figure 3 illustrates the air/ground communications paths of a typical MSFN station. The MSFN stations have the capability to transfer the output of either (or both) USB and VHF receivers to MCC over the NET 1 circuit through switch actuation at the Communications Technicians (Comm-Tech) Console.

Spacecraft voice communications are connected from the sites to MCC through a 4-wire conferencing system controlled at GSFC as shown in Figure 2. In the configuration used for this mission, each site had access to both the transmit and receive side of the NET 1 circuit through the transfer keys. Spacecraft voice communications transfer from one MSFN station to the next was performed on an elapsed time basis without positive determination that the next MSFN station had good communications before the present MSFN site disconnected its voice signal from the net.

Each MSFN station has at least two USB receivers and two VHF receivers; one to be used as a quick transfer back up for the other. In the VHF Duplex B mode, however, (which was used until after Apollo 7 passed over Canary Islands), the prime VHF system had no back up receivers because one VHF ground receiver was pretuned to the 259.7 mHz carrier while the other was tuned to 296.8 mHz, the frequency used in the simplex A mode employed for orbital communications.

In examining Figure 1, it must be remembered that the contacts listed for the various MSFN stations were obtained from recordings of USB and VHF voice taken at the Communications Technicians Console at the site. Each recording contained both the up voice to the CSM as received from MCC (once the transfer key was closed) and the down voice from the CSM from whichever receiver was patched to provide the voice for the net. Therefore, these recordings show what was presented to the respective transmitter modulators, not necessarily what was transmitted at radio frequency to the spacecraft. Likewise, the down voice on the same recording shows the output of the receiver, but not necessarily what was on NET 1 because that again depends on the position of the transfer keys at the Communications Technicians Console. It also appears that in the network configuration used for Apollo 7, the receive side of the VHF recording made at the site will also contain whatever else is on the receive side of the NET 1 circuit if the local transfer key is closed at the Comm Tech Console.

3.0 Results

The following observations were made from notes taken in real time by the Bellcomm observers and from voice recordings from some of the MSFN sites having contact during the launch phase. The letters in parenthesis which are noted in the following paragraphs are keyed to the corresponding circled letters on Figure 1.

3.1 MSFN Station at Cape Kennedy (GMIL)

3.1.1 USB Down Voice

Recordings indicated that good quality voice was available at the output of the USB receiver from lift-off to Loss of Signal (LOS) at GMIL (about 9^m: 44^s GET). Several bursts of static were present from 1^m: 30^s GET, predominating at 1^m:45^s, but these were never strong enough to mask the spacecraft voice signal. Comparison of this recording and the Black 3 channel of the KSC Operational Intercommunication System-Audio (OIS-A) circuit recording for this time period bear remarkable similarities as to voice quality, message content, duration and amplitude of static bursts. It is therefore believed that the GMIL USB receiver and not the special VHF wideband receiver as specified for the prelaunch configuration was connected to the Black 3 channel after launch. A recording of the special wideband VHF receiver output was not available for comparative analysis.

3.1.2 USB Up Voice

Good voice quality from the Blockhouse on the Astrolaunch circuit and MCC on NET 1 is present on the uplink recordings from lift-off to 2^m: 05^s GET when the up voice was disconnected from NET 1 in accordance with the station handover plan.

3.1.3 VHF Down Voice

Good quality voice is heard from lift-off to GMIL LOS at 9^m: 45^s (GET)except for some static around 1^m: 35^s and two missing spacecraft transmissions: (a) at 1^m: 45^s "EDS MANUAL" and (b) 1^m: 52^s, "ROGER ONE CHARLIE." These transmissions were clearly heard on the USB recordings (and Black 3 OIS channel) but since only VHF was connected to NET 1, MCC did not receive the missing spacecraft messages (Key-A). The VHF receiver output was disconnected from NET 1 at 2^m: 05^s (GET) in the middle of the spacecraft transmission, "ROGER, WE'RE GO/HERE JACK."

3.1.4 VHF Up Voice

Essentially the same comments apply as for the USB up voice (Para. 3.1.2) because the station was simultaneously transmitting USB and VHF from the same inputs although the spacecraft had the USB receiver volume controls turned down and was only hearing VHF. A post flight report indicated some doubt as to whether the signals of "LIFT-OFF" and "CLEAR THE TOWER" originated at KSC were actually transmitted to the spacecraft because the crew did not recall hearing them. LC-34 Blockhouse has voice communications control until the space vehicle successfully clears the tower, at which time the control shifts to MCC. It is important to know that the Blockhouse can talk to the spacecraft during approximately the first 10 seconds after lift-off because that is the time when critical abort advisory messages would be transmitted.

Recordings made on monitoring receivers definitely established that the "LIFT-OFF" and "CLEAR OF THE TOWER" were transmitted on USB and VHF from GMIL. The lift-off call out came at T + 2 seconds, slightly overlapping the end of the spacecraft transmission of "LIFT-OFF AND CLOCKS STARTED" at 1 sec. (GET). The "CLEAR OF THE TOWER" message was heard at $0^m: 07^s$ (GET), but at a slightly reduced level than the other up-linked transmissions.

3.1.5 Explanation of Observed Anomalies

The missing transmissions (Key A) from the VHF recording (and NET 1) occurred at a time when the VHF carrier power received at GMIL had a pronounced dip. The dip is believed to have been caused by a combination of poor look angles to the spacecraft antennas (GMIL line-of-sight is only 2 to 4 degrees off the longitudual axis of the space vehicle looking at the tail), and flame attenuation from the booster. The USB received power vs. time curve closely followed the premission predictions including a dip in received power occurring at the same time as the VHF dip. While the signal attenuation was not sufficient to break USB lock, some static was heard on the USB voice tape at that time ($1^m: 45^s$) and the telemetry bit errors and frame synch errors increased.

The dip in the VHF received signal showed an attenuation of about 35 dB. The lowest received signal level, however, was still approximately 20 dB higher than the 90% word

intelligibility level for a properly adjusted R278 VHF receiver. The loss of the VHF down link transmissions at this time could have been caused by the setting of the squelch circuit which quieted the R278 receiver at a threshold level which was too high for the received VHF signal power. This might have been an equipment adjustment problem.

The loss of "..../HERE JACK" portion of the $2^m: 05^s$ message was due to disconnecting the GMIL station from NET 1 without waiting for the message to be completed.

3.2 MSFN Station at Grand Bahama Island (GBM-USB Site, GBI-VHF Site)

3.2.1 USB Down Voice

The USB down voice part of the recording indicated a clear but low level signal from the $3^m: 13^s$ GET spacecraft transmission "HOUSTON, DO YOU READ APOLLO 7?" to $\sim 7^m: 03^s$ (GET) when the speech level increases but becomes garbled. The spacecraft transmissions remained garbled until $8^m: 08^s$ (GET) when the circuit was apparently disconnected from the net. (A key click could be heard along with a characteristic shift in background noise level). (Key E)

3.2.2 USB Up Voice

First up-link voice heard on the GBM USB recording was at $3^m: 15^s$ (GET) "ROGER - FIVE, FIVE, WALLY - YOU'RE LOOKING GOOD." Up voice from NET 1 was of good quality until $8^m: 08^s$ (GET) when GBM was disconnected from NET 1. There was no GBM station recording of MCC voice transmissions from the GMIL disconnect at $2^m: 05^s$ until the $3^m: 15^s$ (GET) message indicating a possible loss of up-link capability on USB during this period (Key B)

3.2.3 VHF Down Voice

The first recorded spacecraft voice was at $1^m: 45^s$ (GET)- "EDS - MANUAL", (one of the missing messages from the GMIL VHF and the MCC NET 1 recordings). The voice was of good quality until LOS at $10^m: 26^s$ (GET) with the following exceptions: the last 30 seconds was weak but readable, and a strong garble occurred between $7^m: 00^s$ and $8^m: 08^s$ (GET). The garbled portion was identical in characteristics to that heard on the GBM USB recording.

3.2.4 VHF Up Voice

Good quality MCC transmissions were heard on this recording from 3^m: 15^s to 8^m: 08^s GET, the same period covered by the GBM USB up voice, indicating a simultaneous feed to the VHF and USB transmitters.

3.2.5 Explanation of Observed Anomalies

It appears that GBM (USB)/GBI (VHF) station voice was not connected to NET 1 until 3^m: 13^s (GET). This left MCC without voice communications (up or down) to the spacecraft from the time (2^m: 05^s) GMIL went "local" until GBM/GBI went "remote" (3^m: 13^s). The planned handover of uplink and downlink communications was to occur at 2^m: 00^s GET.

GBM/GBI remained connected to NET 1 circuit until 8^m: 08^s (GET), overlapping the BDA transmission and reception by 68 seconds. The planned handover to BDA was to be at 7^m: 00^s (GET). The garbled GBM/GBI down voice recordings during this period are believed to be caused by the garbled receiver at BDA which as connected to NET 1 at this time. (see para. 3.3.5).

3.3 MSFN Station at Bermuda (BDA)

3.3.1 USB Down Voice

The first intelligible spacecraft transmission heard on this recording was part of the 6^m: 32^s (GET) "KIND OF DARK /ON TOP" message when USB lock was briefly acquired. Then at 7^m: 00^s, the recording becomes garbled and remains so until 9^m: 16^s (GET) when it clears up following a static burst and remains good until disconnected from the voice network at 12^m: 00^s (GET) (Key E).

3.3.2 USB Up Voice

Good voice was heard on the tape from 7^m: 06^s (GET) when the up-link was apparently connected to NET 1 until the completion of the 11^m: 57^s (GET) transmission when BDA disconnected to handover the up-link to the Vanguard. There was a period of about 30 seconds following a static burst at 9^m: 06^s when key clicks and a slight shift in background noise level was heard. The 9^m: 20^s transmission "I COULDN'T MAKE IT OUT WALLY, BUT YOU'RE LOOKING REAL GOOD" was not

observed on the S-Band tape - although it was on the VHF up tape. It was also observed that the first syllable or two of the up-link transmissions were missing from the BDA USB recordings, but not from the VHF up voice recording which were understood to be fed simultaneously from the GOSS Conference channel (NET 1).

3.3.3 VHF Down Voice

The spacecraft was first heard on these recordings at $3^m: 41^s$ GET. The speech was badly garbled and mostly unintelligible until $9^m: 40^s$ GET when the background noise changed level and characteristic (Key C). The recording then became loud and clear and remained so until $14^m: 15^s$ when it went off in a burst of static (Key D).

The contact chart (Figure 1) shows that at the time the BDA site connected this garbled VHF receiver to the voice network, their own USB recording became garbled and the garbled voice also appeared at Houston. Although the same garble is shown on the receiver side of the GMB/GBI recordings, it is believed the garble was actually on the transmit or up-link side of NET 1 and remained present until GBM/GBI disconnected from the net at $8^m: 08^s$. Subsequent discussions with GSFC personnel confirm this observation in that all these sites had access simultaneously to both sides of the GOSS Conference Circuit through their Comm Tech panel transfer keys. If this was the case, only the lack of the Quindar keying tone prevented the recirculating BDA garbled downlink from being retransmitted from GBM/GBI. Since GBM/GBI remained connected to NET 1 for 68 seconds after BDA connected, it is assumed that in addition to the contamination caused by the BDA VHF receiver, both sites were transmitting MCC messages (VHF and USB) to the spacecraft during this time.

3.3.4 VHF Up Voice

The recording shows MCC voice from NET 1 appearing at the same time and of the same quality as the USB voice which was expected since this site was also in the simultaneous USB and VHF transmission mode. The difference here, however, is that at $9^m: 40^s$ (GET) the background noise changed tone and no more MCC transmissions were heard. For reasons not yet known, the VHF up-link was disconnected from the net at this time, and the MCC transmissions of predicted SECO and "MODE FOUR" which were present on the USB recordings were not transmitted on VHF. The spacecraft did not hear these messages because they apparently still had their USB receiver volume controls set at minimum as planned (Key G).

3.3.5 Explanation of Observed Anomalies

Bermuda appears to have had a garbled VHF receiver which garbled the voice network from 7^m: 00^s until SECO 10^m: 20^s GET, although post-mission testing did not show the receiver to be out of alignment.

The dramatic improvement in down voice quality at "SECO" as heard on NET 1 is believed to be the USB receiver output.

The BDA USB receiver output was simultaneously connected to NET 1 with the bad VHF receiver until about 9^m: 12^s when it was removed. The garbled feedback from the bad VHF receiver was isolated from the receive side at this time, and the USB output recording became good until the receiver was disconnected along with the up-link at 12^m: 00^s (GET), the planned handover time for the Vanguard. It is believed that although no more voice appeared on the USB recording, the USB receiver output was transferred to NET 1 at "SECO" and the VHF recording from that time until 14^m: 15^s was the better USB receiver.

The VHF up voice at BDA was removed from the net early (9^m: 40^s instead of 12^m: 00^s GET) causing the spacecraft to miss some important transmissions from MCC.

3.4 MSFN Station Ship USNS Vanguard (VAN)

No voice recordings from the Vanguard were available for review, but from examination of the MCC NET 1 transcript it appears that the Vanguard was not continuously connected to the net on VHF. Two short periods of weak, but readable voice from the spacecraft were observed at 13^m: 05^s GET and 16^m: 28^s GET. It is not known if the spacecraft heard any transmissions via the Vanguard, but the CSM crew did not answer repeated calls from MCC during this time. (Key H)

The Vanguard reportedly had USB communications with the spacecraft, but apparently not VHF communications. Since the spacecraft was not up on USB, it is doubtful that they received any transmissions from MCC during this pass. MCC recorded only two brief spacecraft messages during this time, from which receiver is not known.

3.5 MSFN Station Canary Island (CYI)

3.5.1 USB Down Voice

USB down voice was weak and slightly garbled. The recording was at a lower level than the uplink voice on the same tape (see para. 3.5.2).

3.5.2 USB Up Voice

The first up voice heard on the CYI USB recording was the 18^m: 52^s MCC transmission, "APOLLO 7 HOUSTON, HOW ARE YOU READING NOW?" The dubbed recording which was examined was of poor quality and not considered representative of the circuit as heard at the CYI station. Up voice was readable until 24 minutes (GET) when the circuit was disconnected from the network.

3.5.3 VHF Down Voice

First voice heard was the 17^m: 03^s (GET) "ROGER" from the spacecraft. The down voice on the station recording and NET 1 was somewhat garbled and at times weak, but could be occasionally understood. (Key I) It is believed some down voice was lost about 19^m: 30^s, while the station was reconfiguring for Simplex A VHF reception. At 19^m: 30^s (GET), the background noise increased slightly and the spacecraft voice as subsequently heard on NET 1 at MCC improved markedly with the VHF Simplex A Configuration. (Key J) The down voice remained loud and clear until the station went off the net at 24^m: 05^s GET.

3.5.4 VHF Up Voice

The first MCC voice heard on this recording was "MARK 17 MINUTES, GET." Voice quality was fair and signal level was satisfactory. Readable voice was heard until 24^m: 00^s GET when CYI disconnected from the network.

3.5.5 Explanation of Observed Anomalies

The CYI station apparently had a garbling VHF receiver similar to the one at BDA. Switching to the Simplex A mode got around the difficulty.

4.0 CONCLUSIONS

One or possibly two poor VHF receivers (BDA and CYI), improper equipment adjustments, and procedural errors in voice switching at three of the MSFN sites covering the first twenty-four minutes of flight resulted in unsatisfactory voice communications during the Apollo 7 launch phase. At least two sites (GMIL and GBM/GBI) had good voice signals in excess of their nominal network participation times. However, because the handover procedures stipulated connection to the NET 1 circuit (GOSS Conference) by the clock without considering signal quality, the better voice signals were not received at the Mission Control Center. By linking the sites together on a party line, the bad receiver at BDA degraded the entire voice network while good voice signals as locally received were not connected to MCC.

Handover procedures for the down voice communication should be coordinated at a central point such as the GSFC switching center so that the best available voice quality could be connected to the Mission Control Center. Centralized voice network coordination would also prevent the disconnecting of spacecraft transmissions to MCC in the middle of a message.

L. A. Ferrara

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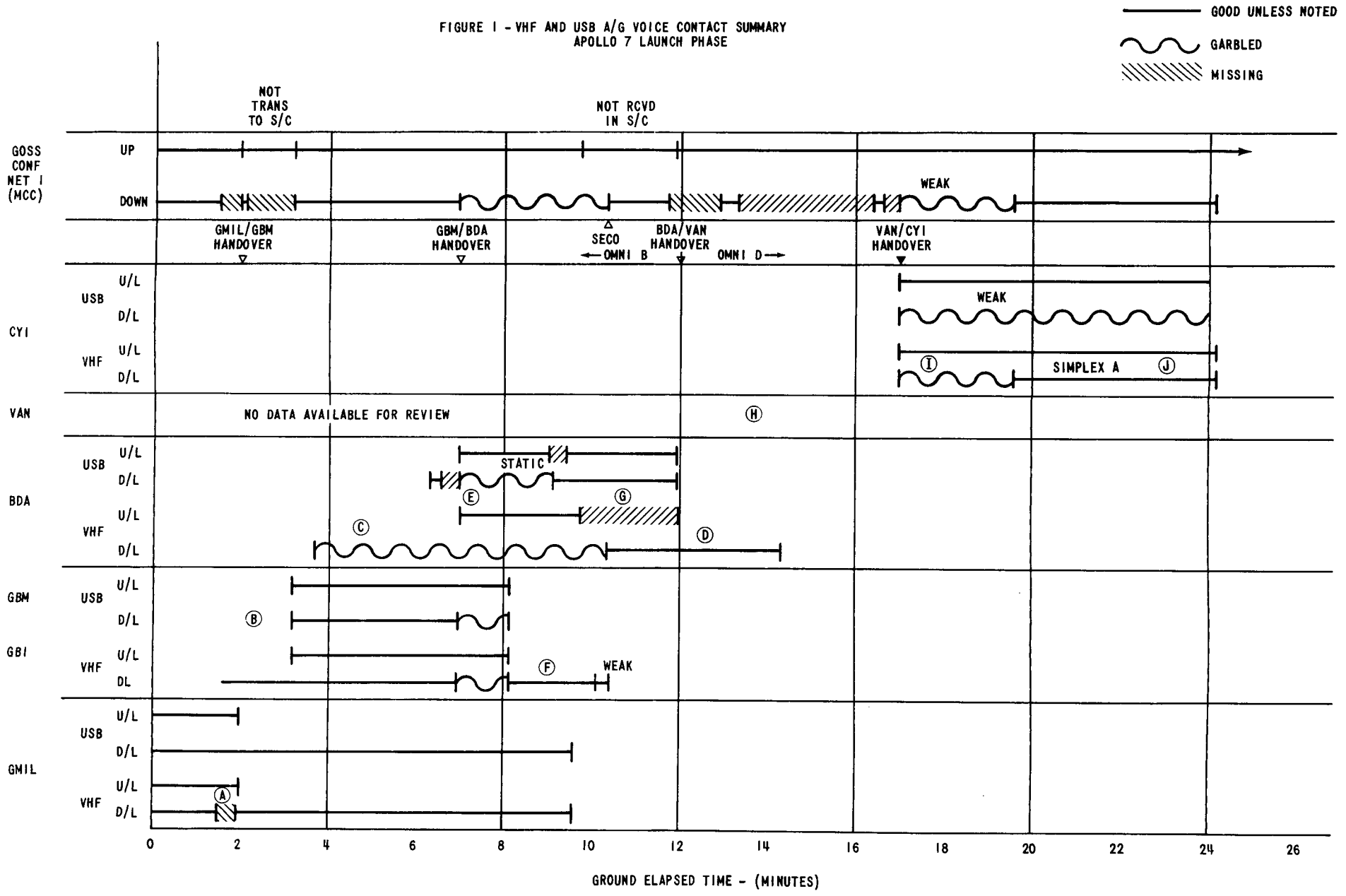
Attachments
Figures I-III

FIGURE I - VHF AND USB A/G VOICE CONTACT SUMMARY
APOLLO 7 LAUNCH PHASE



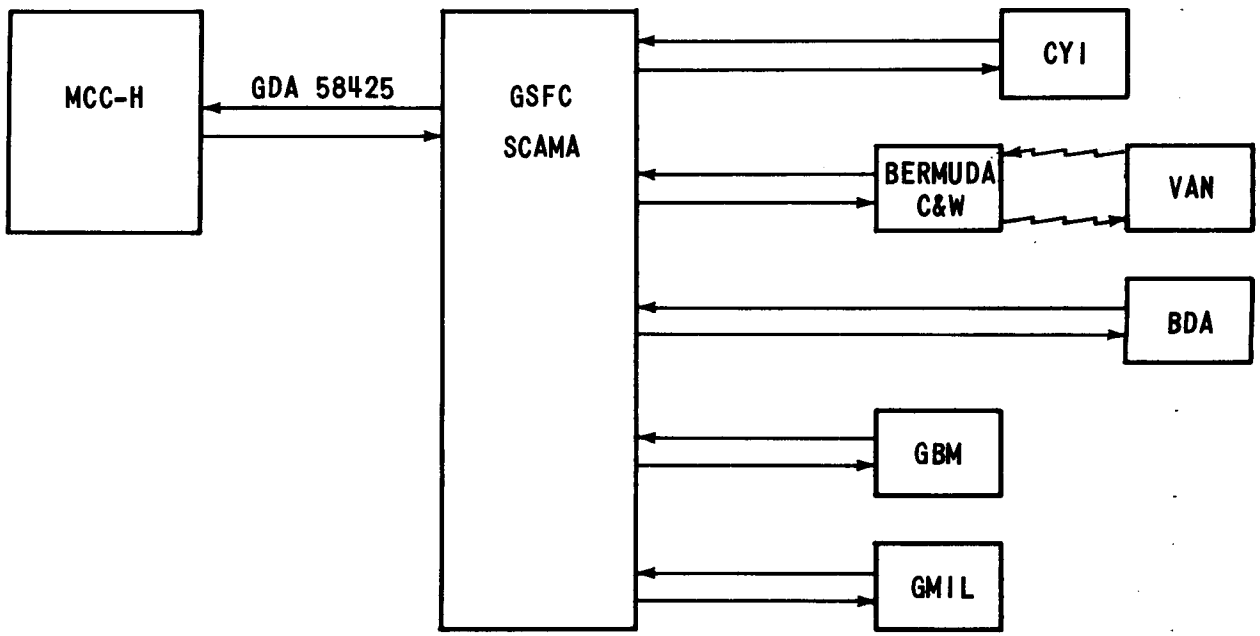


FIGURE 2 - GOSS CONFERENCE VOICE NETWORK (NET I)
FOR AS-205 LAUNCH COVERAGE

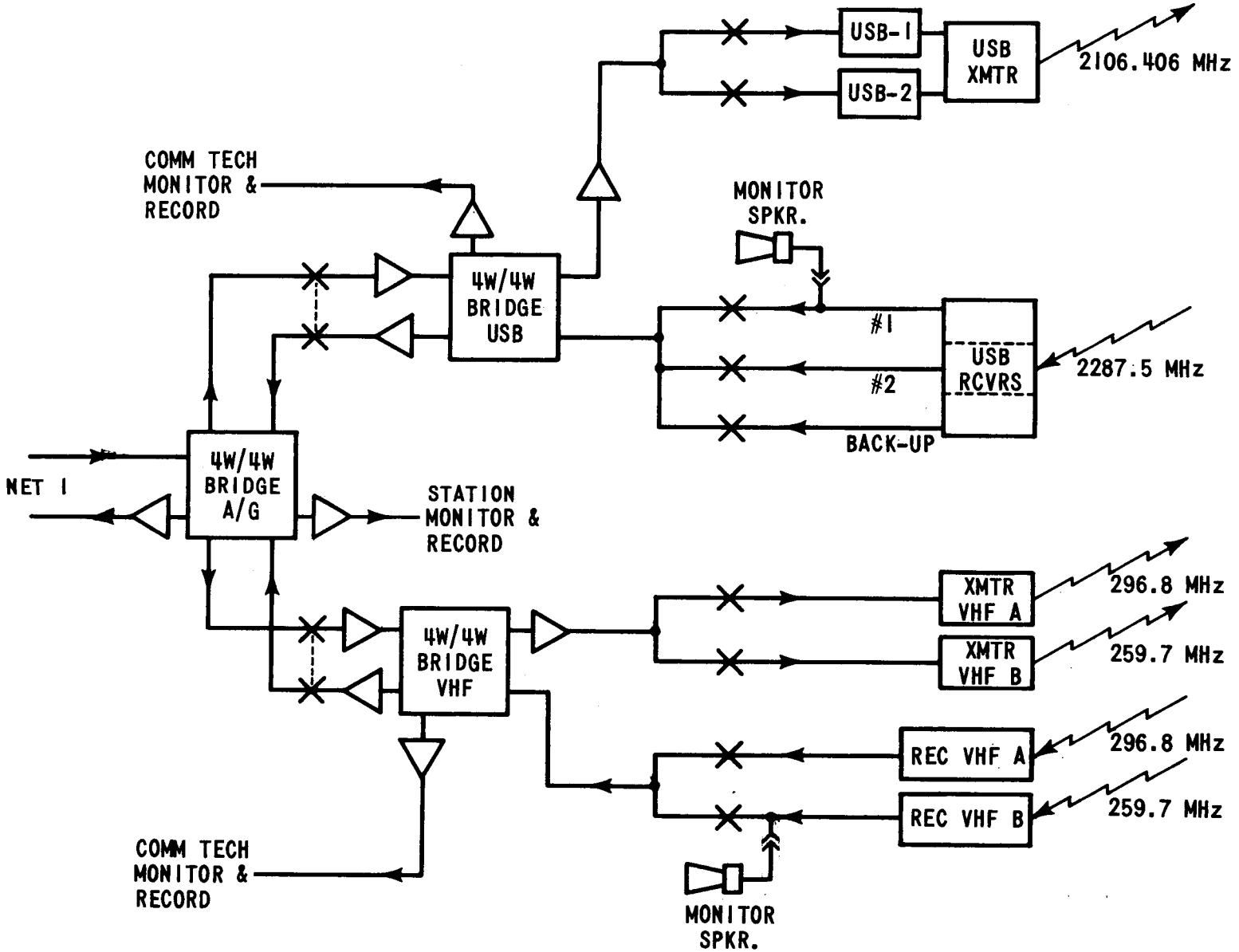


FIGURE 3 - TYPICAL COMMUNICATION TECHNICIAN CONSOLE
AIR-GROUND VOICE SWITCHING CAPABILITY

BELLCOMM, INC.

Subject: Apollo 7 Launch Phase Air/ Ground Voice Contact Analysis

From: L. A. Ferrara

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